

## The Minas de Henarejos basin (Iberian Ranges, Central Spain): precursor of the Mesozoic rifting or a relict of the late Variscan orogeny? New sedimentological, structural and biostratigraphic data

La cuenca de Minas de Henarejos (Cordillera Ibérica, España): ¿Precursora de un rifting mesozoico o relict de la orogenia Varisca? Nuevos datos sedimentológicos, estructurales y biostratigráficos

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### Abstract

The tiny outcrop of the mining area of Minas de Henarejos is unique among the early post-Variscan basins of the Iberian Ranges, Central Spain, for several reasons: Its age, considered up now to be Late Carboniferous (Stephanian B-C), its syn-sedimentary compressional structures and the thick coal beds in the upper part of the section. A re-assessment of the biostratigraphic range of its macroflora shows that it is representative of the hygrophytic assemblage that ranges from the Late Carboniferous to the Early Permian, coeval with the so-called “Autunian” assemblages. Nothing prevents this basin to be considered coeval with other continental basins of Early Permian age in the Iberian Ranges. Compressional structures can be related to a right restraining bend in the sinistral N-S Teruel strike-slip fault system that created a synformal basin in the underthrust block.

**Keywords:** Autunian, Lower Permian, Stephanian B-C, hygrophytic macroflora, Carboniferous

### Resumen

El pequeño afloramiento de la zona minera de Minas de Henarejos es único entre aquellos que conforman las cuencas de las primeras fases de los últimos estadios de la orogenia Varisca en la Cordillera Ibérica, en el Centro de España, debido a diferentes motivos: su edad, considerada hasta nuestros días como Carbonífero Superior (Estefaniense B-C), sus estructuras sinsedimentarias de tipo compresional y las potentes capas de carbón que aparecen en la parte más alta de la serie. Una revisión del rango biostratigráfico de su macroflora muestra que ésta constituye una asociación higrofítica que abarca desde el final del Carbonífero hasta las etapas iniciales del Pérmico, coetánea con la también denominada “asociación Autuniense”. No hay datos que estén en contra de que esta cuenca sea coetánea con otras cuencas continentales del Pérmico Inferior de la Cordillera Ibérica. Las estructuras compresionales podrían estar relacionadas con un bucle compresivo diestro dentro del sistema de fracturación de desgarre de dirección N-S de la denominada falla de Teruel, creando una cuenca sinformal en el bloque que quedaba hundido.

**Palabras clave:** Autuniense, Pérmico Inferior, Estefeniense B-C, macroflora higrofítica

## 1. Introduction

The Variscan orogeny developed in the Iberian Peninsula between the late Devonian and the late Carboniferous and the three main phases of compressive deformation (D1, D2 and D3) that ended in the Westphalian B times (i.e., lower Moscovian, about 310 M.a.) are now well described and constrained in time in a wealth of papers (see Martínez-Catalán *et al.*, 1990, 1992, 1999, 2003; Pérez-Estaún *et al.*, 1993, 1994; Ábalos *et al.*, 2002; Simancas and Pérez-Estaún, 2004). When the Alpine cycle of extensional tectonics started has been debated. It is a difficult question to solve because the long period between the late Westphalian and the Late Permian (Thuringian or Lopingian), that is, from about 310 M.a. to 253 M.a., is recorded only in small, isolated outcrops of continental siliciclastic rocks and/or andesitic-basaltic volcanic rocks, all of them considered of Early Permian age.

In the Iberian Ranges (Fig. 1A), sediments and associated volcanic rocks of Early Permian age are always unconformity-bounded, postdating the emplacement of the “tardi-Variscan” granitoids and associated metamorphic events (Sopeña *et al.*, 1988; López-Gómez and Arche, 1992, 1993; López-Gómez *et al.*, 2002; Lago *et al.*, 2004). The Pyrenees have more complete rock record for this period of time than other basins in the Iberian Peninsula (Lucas and Gisbert, 1996). The rock record of these latter basins elsewhere in Spain represents only a tiny fraction of time of this long period (Fig. 2), so it is reasonable that the details of the Variscan-Alpine transition are still open to several alternative interpretations. The Minas de Henarejos area, in the Iberian Ranges, Central Spain (Fig. 1A), shows unique sedimentological, structural and paleontological features that could fill a gap in the knowledge of this period and a better understanding of the Variscan-Alpine transition in Central Spain. In this paper, we present new data on the Minas de Henarejos basin, in the SE Iberian Ranges, Central Spain, and a discussion of the sedimentologic, paleobotanic and structural characteristics of the continental basins of Central Spain in order to clarify its age and tectono-sedimentary evolution. The terms Variscan and Alpine do not have stratigraphic implications in this paper and are used as broad successive tectonic cycles.

## 2. Tectono-stratigraphic framework

The general interpretation of the Late Carboniferous-Early Permian period of time and the origin and evolution of the related sedimentary basins is that of a long transition between the Variscan compression and the extensional Alpine events, dominated by a dextral strike-slip

regime in the Iberian Peninsula for most of the Permian, controlled along two E-W major dextral strike-slip fault systems at its northern and southern limits that created small pull-apart basins. The strike-slip regime is considered coeval with the lithospheric collapse of the Variscan belt (Doblas *et al.*, 1994 a, b; González-Casado *et al.*, 1996). True Alpine extension, according to these authors, started only during the Late Permian (Sopeña and Sánchez-Moya, 2004). This implies that substantial change in the stress field inside the Iberian microplate took place at the end of this transitional period and the enigmatic tectono-sedimentary character of the proposed Late Variscan transitional period is not clearly defined, nor the reasons for this stress field change and style of deformation between the Early and the Late Permian (McCann *et al.*, 2006). The precise definition of the Carboniferous/Permian boundary in the continental basins of Western Europe is also still far from settled (Broutin *et al.*, 1999; McCann *et al.*, 2006).

The alternative interpretation proposed by Arche and López-Gómez (1992, 1996) and López-Gómez *et al.* (2002), based on earlier ideas exposed by Arthaud and Matte (1977) and Menard and Molnar (1988), relates the origin and evolution of these basins to a dominant extensional tectonic regime in the interior of the Iberian microplate along NW-SE normal faults and N-S associated sinistral strike-slip faults as an intraplate tectonic response to the stress at the southern and northern margins of the microplate during the lithospheric collapse of the roots of the Variscan Orogen, starting immediately after the end of the Variscan compressive stress regime at the end of the Carboniferous, that is, a precursor extensional tectonic regime of the generalised Alpine extension developed from Late Permian times onwards in the Iberian microplate.

To elucidate which of the two hypotheses better explains field data it is crucial to evaluate the biostratigraphic data of the Late Carboniferous-Early Permian continental record in the basins of the Iberian Peninsula, the kinematics of their syn-sedimentary basin boundary faults and the correlative internal deformation of the sedimentary record.

## 3. Main characteristics of the Early Permian basins in the Iberian Ranges and related areas in northern and southern Iberia.

Early Permian basins in the Iberian Microplate are located in the Pyrenean-Cantabrian Zone, the Iberian Ranges and the southern margin of the Iberian Massif (Fig. 1A). They were small, isolated continental basins with internal drainage. Some of them with associated volcanic and



Fig. 1.- A- Iberian Ranges and related Alpine structures in central-eastern Spain. B- Main extensional fault systems and related strike-slip transfer fault systems in the Iberian domain during the Permian-Early Triassic period.

Fig. 1.- A- La Cordillera Ibérica y sus estructuras alpinas relacionadas en el centro-este de España. B- Sistemas de fractura de extensión más importantes relacionados con los sistemas de fracturación de desgarre en el dominio ibérico durante el periodo de tiempo Pérmico-Triásico inicial.

volcanoclastic rocks at the base and with very different subsidence rates and sedimentary record, ranging from 20 m to more than 700 m (López-Gómez *et al.*, 2002; Sopena and Sánchez-Moya, 2004). Biostratigraphic age of these sediments is based on macro- and microfloristic assemblages (Sopena, 1979; Ramos *et al.*, 1976; Doubin-

ger *et al.*, 1978; Wagner and Martínez, 1982; Martínez, 1991; Lucas and Gisbert, 1996; Rey and Ramos, 1991; Broutin, 1977, 1981), but the estimated time ranges of these assemblages must be re-evaluated.

The Early Permian rocks of the Cantabrian Zone lie unconformably on the variscan basement and were depo-



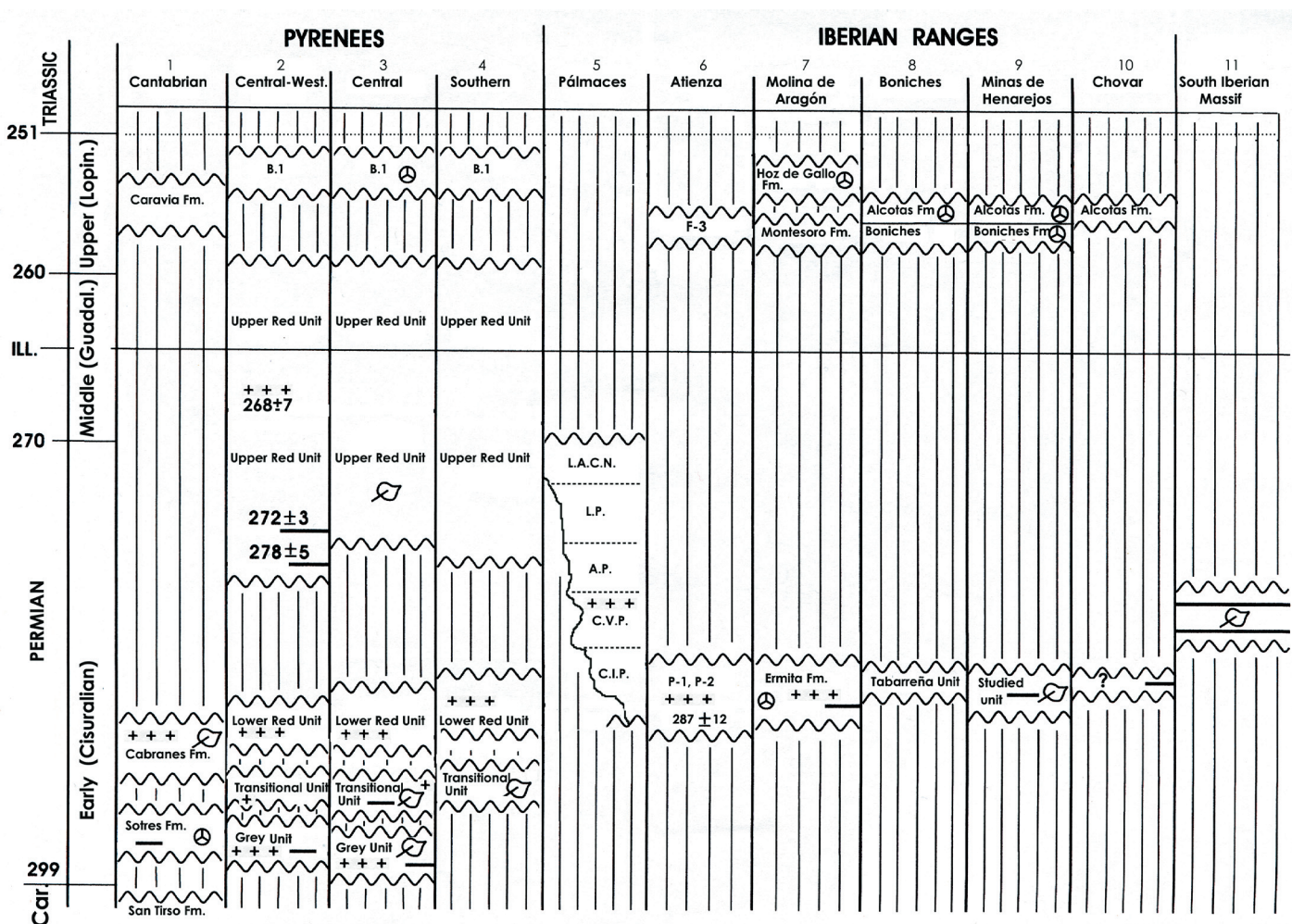


Fig. 2.- The Permian rock record in central, north and northeastern Iberia. Data from Martínez (1991), Lucas and Gisbert (1996), Sopena (1979), Hernando *et al.* (1980), Ramos (1979), López-Gómez and Arche (1993) and Broutin (1977).

Fig.2.- Registro de rocas del Pérmico en el Centro y NE de Iberia. Datos de Martínez (1991), Lucas y Gisbert (1996), Sopena (1979), Hernando *et al.* (1980), Ramos (1979), (López-Gómez y Arche (1993) y Brutin (1977).

sited in several isolated continental basins trending E-W (García-Mondéjar *et al.*, 1989) (Fig. 2). The lower part of the sedimentary record consists of red conglomerates, sandstones and siltstones, volcanoclastic sandstones and some black siltstones, coal beds and algal limestones (Sotres Formation) in its upper part (Martínez, 1991). Macrofloral associations are dominated by *Autunia conferta*, *Culmitzschia frondosa*, *Taeniopteris fallax* and *Neuropteris* sp. (Wagner and Martínez, 1982), of Early Permian (Autunian) age, equivalent to the Early Autunian macrofloral assemblages of the classic Autun Basin in central France.

The upper part (Cabranes Formation) consists of red conglomerates, sandstones and siltstones (Martínez, 1991), lying unconformably on the former unit; they contain a macrofloral assemblage of identical composition and age than the previous one. A major tectonic event of Early Permian age is therefore recorded in the Cantabrian domain.

The Pyrenees Chain contains the thickest sedimentary-volcanic record of Late Carboniferous (?)– Early Permian age in the Iberian Peninsula (Lucas and Gisbert, 1996; Debon *et al.*, 1996) (Fig. 2). Several isolated continental basins trending E-W contain more than 1000 m of grey siltstones, coal measures and thick volcanic and volcanoclastic successions at the base and red conglomerates sandstones and siltstones at the top. A detailed description of these basins is out of the scope of this paper, but it is important to mention that the macroflora found in the lower part, dominated by *Mixoneura ovata*, *Linopteris brongniarti*, *Alethopteris gandini* and *Sphenophyllum costae* (Nagtegaal, 1969) is usually considered to be Late Carboniferous (Stephanian B-C). However, the intercalated volcanic rocks have been dated as  $278 \pm 5$  M.a. (Early Permian, Autunian) (Briqueu and Innocent, 1993). This apparent contradiction is found in many Spanish and European basins and to contribute to its elucidation is one of the main goals of this paper. The sedimentary infilling

of these basins show several angular unconformities specially important between the upper red-bed unit (U.R.U.) and the grey or variegated lower ones (L.R.U.) and an expansive paleogeographic evolution over the variscan basement from base to top.

The Early Permian sediments and associated volcanic rocks of the Iberian Ranges and NE Central System (Figs. 2, 3), in Central Spain, range in thickness from 20 to more than 1000 m, were also deposited in small, isolated continental basins with internal drainage, some of them with clear half-graben geometry. This area has yielded the richest macro- and microfloral assemblages of this age in the Iberian Peninsula and some reliable absolute ages of the volcanic rocks (Sopeña, 1979; Sopeña *et al.*, 1974, 1977; Hernando *et al.*, 1980; Ramos, 1979; Ramos *et al.*, 1976; Pérez-Arlucea and Sopeña, 1985; López-Gómez and Arche, 1993; De la Peña *et al.*, 1977; Rey and Ramos, 1991; Conte *et al.*, 1987; Lago *et al.*, 2004).

The lower part of the Early Permian succession in the NW Iberian Ranges, where the macroflora remains have been found, contains volcanic and/or volcanoclastic ro-

cks associated to grey siltstones and sandstones (Fig. 3, numbers 1, 2, 3), and is conformably overlain by an upper part composed by red sandstones, conglomerates and siltstones, usually barren of organic remains. In the SE Iberian Ranges, the Early Permian is represented only by thin red breccias in the Cañete region and by volcanic rocks in the Fombuena-Montalban region (Figs. 1A and numbers 4, 5 in Fig. 3).

The rich paleoflora of Retiendas and Valdesotos (Central System) (Sopeña, 1979) is dominated by *Autunia conferta*, *Lodevia nicklesi*, *Rachiphyllum schenckii*, *Walchia* sp. and *Baiera* sp. of Autunian affinities, but also contains forms like *Sphenophyllum angustiformis*, *Odontopteris obtusa*, *Pecopteris densifolia* and *Calamites suckowi* of late Stephanian (Latest Carboniferous) affinities. These associations are similar to the macrofloras of the upper part of the early Autunian of the Autun Basin, Northern France (Broutin *et al.*, 1999).

The microfloral associations have been found in many localities (Sopeña *et al.*, 1988, 1995; Sopeña and Sánchez-Moya, 2004) and are dominated by *Potonieisporites*

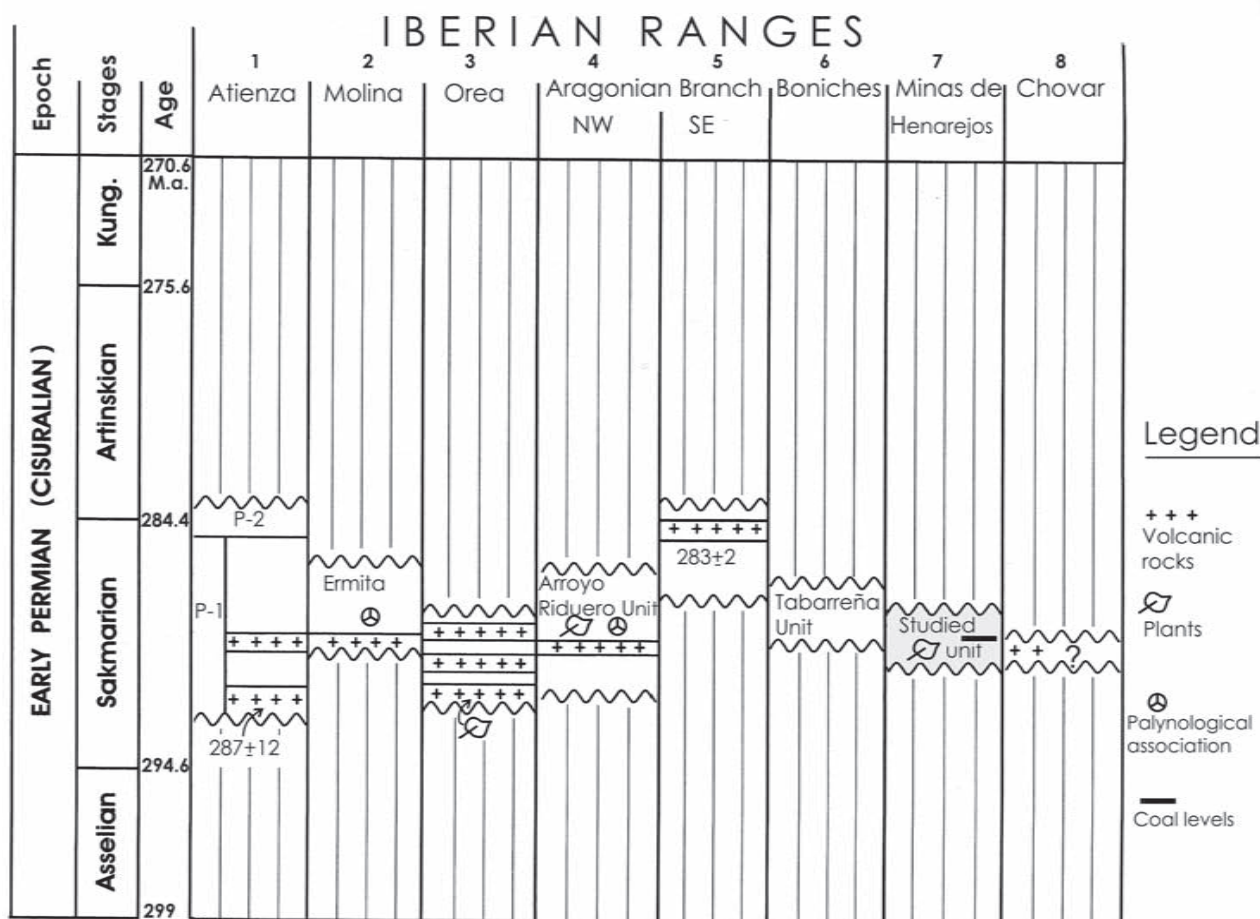


Fig. 3.- The Early Permian rock record in the Iberian Ranges. Data from Sopeña (1979), Hernando *et al.* (1980), Ramos (1979), López-Gómez *et al.* (2002) and Lago *et al.* (2004).

Fig. 3.- Registro de rocas del Pérmico Inferior en la Cordillera Ibérica. Datos obtenidos de Sopeña (1979), Hernando *et al.* (1980), Ramos (1979), López-Gómez *et al.* (2002) y Lago *et al.* (2004).



*novicus*, *Vittatina costabilis*, *Allisporites* sp. and *Leiotriletes* sp. of Early Permian (early Autunian, zone A2 of Doubringer, 1974, in the Autun Basin). This is the standard reference for biostratigraphic zonation of continental deposits of Early Permian age in Western Europe up to now.

The precise age of these macro- and microfloristic assemblages in Western Europe, as in Spain, is still a matter of debate because the classical concept of the base of the Autunian, that is, the Carboniferous-Permian boundary, located at the base of the red "Lower Rotliegend" facies and the associated first appearance of *Walchia* and *Callipteris* is no longer valid. Indeed, these macrofloras have been found in the underlying grey formations associated with a different, dominant "Stephanian" macroflora. The lateral transition from grey, lacustrine facies with coal measures to red fluvial facies is frequent in many French and German basins (Broutin *et al.*, 1999, for a review). Accordingly, the colour-facies criteria is rejected as a marker of the Carboniferous-Permian boundary.

The age range of the two contrasting, coeval and environmentally controlled macrofloras, the hygrophytic "Stephanian" and the xerophytic "early Autunian" should be placed in a time bracket from the late Gzelian (Carboniferous, approx. 303 M.a.) to the middle Sakmarian (Permian, approx. 285 M.a.). No macrofloral nor microfloristic criteria allow for more precision up to now (Broutin *et al.*, 1999; Gorsky *et al.*, 2003). Therefore, the biostratigraphy of the Iberian Ranges deposits also present similar problems.

Two continental rift basins in the southern margin of the Iberian Massif (Fig. 1A, SMIM), the Guadalcanal and Río Viar basins, have yielded a rich macroflora dominated by *Gingophytes* and rare *Callipteris* and microfloras dominated by striated bisaccates (Broutin, 1986); these organic remains are found in the middle part of the sedimentary record, in coal measures that conformably rest on volcanic and volcanoclastic rocks. These associations are late Autunian, younger than the Iberian Ranges-Central System macro- and microfloras.

The Minas de Henarejos basin, has been considered apart from the rest of Early Permian basins in Central Spain for two main reasons: (1) its age is considered to be Late Carboniferous (Stephanian B-C) (Meléndez *et al.*, 1983; Wagner *et al.*, 1985a,b), that is, older than the rest of the basins and (2), internal structure is compressive. Therefore, a tectonic event related to the intrusion of the youngest granitoids and coeval continental collapse of the Variscan Orogen has been proposed during its formation (Doblas *et al.*, 1994a; Capote *et al.*, 2002; Sopena and Sánchez-Moya, 2004).

#### 4. The Minas de Henarejos basin: sedimentological and biostratigraphic data.

The Minas de Henarejos basin is now exposed in a small 600m long by 500m wide outcrop in the Castilian Branch of the Iberian Ranges (Cuenca Province) (Figs. 1, 2 and 3). It contains coal measures that have been exploited several times since 1917. Rich macroflora assemblages have been described by Meléndez *et al.* (1983) and Wagner *et al.* (1985a, b). They are dominated by *Annullaria stellata*, *Pecopteris arborescens*, *Calamites suckovi*, *Neuropteris ovata* and many other Sphenophytes and Filicophytes. These authors define a Late Carboniferous (Stephanian B-C) age to this macroflora, therefore older than any other found in the Iberian Ranges.

Our own structural sections clearly show that the infilling of the basin took place under compressional, synsedimentary regime, again a unique feature in the Iberian Ranges. If the proposed age is correct, then this outcrop is the only remain in the whole Iberian Ranges and central and southern Iberia of a compressive tectonic event older than the extensive (or transtensive) Autunian basins and younger than the latest known Variscan compressive event in the whole of the Iberian Peninsula (Martínez-Catalán *et al.*, 2003). This fact poses a major problem in the interpretation of the tectono-sedimentary evolution of Central Iberia that needs further attention and is the main target of this paper.

Recent open-cast mining works have exposed the complete sedimentary succession (Fig. 4), about 100 m thick, much less than the 350 m previously reported (Meléndez *et al.*, 1983). It shows of two parts: the lower one (from level 1 to level 10) is unconformable on the folded Silurian basement. It consists of metric fining-upwards grey sandstone-siltstone sequences (Fig 5A), interpreted as sandy braided fluvial systems related to distal alluvial fan facies, with paleocurrents towards the N and NW. This part shows a general energy increase towards its top. The upper, conformable part, consists of breccias, sandstones, black slates and coal beds (Fig. 5B, C), containing the rich macroflora described by Meléndez *et al.* (1983) and Wagner *et al.* (1985a, b) (Fig. 4). This interval is interpreted as lacustrine and freshwater swamp deposits and associated small deltas accumulating in an interior basin. The uppermost part of the sedimentary succession is unconformably covered by Late Permian conglomerates, the Boniches Formation, and its top is not exposed (Fig. 5D).

The upper part of the succession is deformed by a series of compressive structures (Fig. 5E, F) that we consider coeval with sedimentation: fan-like sequences thickening away from the thrusts, marked lateral thickness changes in

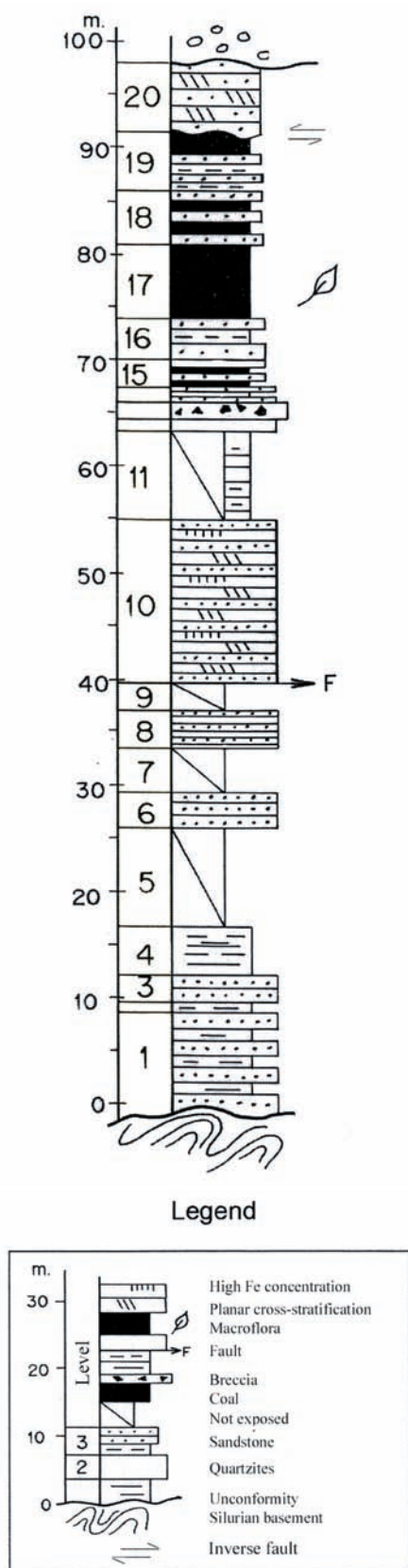


Fig. 4.- Stratigraphic log of the Early Permian rocks of the Minas de Henarejos area, SE Iberian Ranges.

Fig.4.- Columna estratigráfica de las rocas de la base del Pérmico de la zona de Minas de Henarejos, SE de la Cordillera Ibérica.

the coal beds, large scale bed-parallel detachments, small scale normal faults and thrusts, soft sediment folds, etc. The overlying Late Permian conglomerates (Boniches Formation, López-Gómez and Arche, 1997) are unaffected by this compressive event, putting an upper bracket on its age. The origin of the compressive structures will be discussed latter.

The age of the macroflora found in the upper part of the succession must be re-evaluated according to new data from classic french and german basins. As Broutin *et al.* (1999) have demonstrated in some coeval French basins (Lodève, Autun) with very thick sedimentary successions and rich macrofloras, there is a vertical alternation of grey intervals with “Stephanian B-C” macrofloras and red intervals with “Autunian” macrofloras. They demonstrated that both assemblages are coeval and that the former represent hygrophite associations and the latter, xerophyte ones; the vertical succession of floras is thus climatically controlled and any of them can be found in a time interval ranging from the Late Carboniferous to the Early Permian. Consequently, they have very poor biostratigraphic resolution.

The classical concept of the base of the Autunian located at the base of the red “Lower Rotliegend” facies in Central Europe, associated with the first appearance of *Walchia* and *Callipteris* is no longer valid because these fossils have been found in the underlying grey formations associated with a different flora of Carboniferous affinities. The lateral change from grey, lacustrine facies to red fluvial facies is now demonstrated in many French and German Carboniferous-Permian basins (Becq-Giraudon, 1985, 1986; Bonijoly and Castaign, 1984; Broutin *et al.*, 1999).

Therefore, the macroflora of Minas de Henarejos basin is ill constrained in time and its age can be only placed between the Late Carboniferous and the Early Permian. The Minas de Henarejos macroflora may be contemporaneous with the Early Permian floras of different composition described elsewhere in the Iberian Ranges (Virgili *et al.*, 1974, 1984a,b; Ramos *et al.*, 1976; Sopena, 1979) and, consequently, the Minas de Henarejos basin may result from the same tectonic event that created the rest of the so-called Autunian basins in this Range. Different paleofloristic realms could coexist along the Iberian Ranges controlled by different climatic regional conditions and contrasting local relief. The interesting problem of floristic paleodiversity and its climatic and geomorphological controls in the Iberian microplate should be addressed in the future.

The presence of syn-sedimentary compressive structures in the Minas de Henarejos basin (Fig. 5E, F) has not been described up to now and is in sharp contrast with

the extensive nature of coeval basins. The timing and the tectonic or gravitational origin of these structures will be discussed in the next chapter. The age of these basins is younger than the latest “tardi-hercynian” compressive phases in Iberia (Martínez-Catalán *et al.*, 2003) and the exceptional compressive nature of the Minas de Henarejos basin should be explained.

### 5. Compressional structures in the Minas de Henarejos basin: Late Variscan inheritance or early Alpine precursors?

The presence of syn-sedimentary shortening structures in the Minas de Henarejos basin has not been described up to now; this is an important observation because all the coeval Early Permian basins of the Iberian Ranges were deposited under extensional or trans-tensional stress regime (Lago *et al.*, 2004; Sopena and Sánchez-Moya, 2004). Variscan compression ended at the beginning of the Late Carboniferous (late Westphalian) according to Martínez-Catalán *et al.* (2003) and Bea *et al.* (2004). There is always a possibility for a local or regional younger late-variscan compressive event in the central Iberian Ranges, not described up to now, related to the dominant strike-slip tectonic regime during the collapse of the Variscan Orogen proposed by Doblas *et al.* (1994a,b), Arche and López-Gómez (1996) and Capote *et al.* (2002), but this will be a major exception in the whole of Iberia.

The shortening structures are better developed in the eastern margin of the Minas de Henarejos basin and in the upper part of the sedimentary succession (Fig. 5E, F), indicating a progressive deformation of the eastern margin of the basin during the sedimentation. In contrast, no compressive structures are observed in the western margin of the basin.

Elementary kinematic considerations (Fig. 6A) discard a purely compressive regime orientated N-S in Central Iberia caused by the northern and southern major E-W strike-slip fault zones at the edges of the Iberian Plate. Field regional data show that these structures are not found in other basins, from the Cantabrian Mountains, to the N, to the S. Iberian margin, to the S (Ábalos *et al.*, 2002; Martínez-Catalán *et al.*, 2003; Bea *et al.*, 2004). Therefore, the Minas de Henarejos basin shortening structures do not likely represent an exceptional, posthumous Variscan compressional event represented only in this locality. But the same kinematic considerations show that a secondary, antithetic sinistral strike-slip fault system, orientated N-S, can develop associated to the main NW-SE extensional normal fault system in Central Iberia (Fig. 6A, B). Field data show that the Minas de Henare-

jos basin lies on a major N-S lineament, the Teruel Fault System (Fig. 1B), active since the Late Permian (Arche and López-Gómez, 1996) and probably during the Early Permian in some segments.

Local coeval transtensional-transpressive deformation along continental strike-slip fault systems are well documented (Murphy and Burgess, 2006; Rotstein *et al.*, 2005), leading to the creation of pull-apart basins in releasing bends (transtension) and synformal corrugation basins in restraining bends (transpression), caused by small local changes in regional stress field along discrete segments of the main continental strike-slip fault systems. The complexity of resulting basins and associated fault systems along this type of fault arrays is exposed by Christie-Blick and Biddle (1985), Mann *et al.* (1991), Nilsen and Sylvester (1995), among many others.

The syntectonic character of the Minas de Henarejos basin sedimentary infill shortening structures is clearly demonstrated by several criteria:

- a- Increasing thickness towards the eastern margin and associated soft sediment deformations along it, therefore, predating lithification.
- b- Presence of growth strata fans associated to horizontal thrust fault with displacement towards the NW.
- c- Increasing thickness of the coal beds towards the western margin, away from the source area.
- d- Duplication and parasitic folding of the coal beds, again before total lithification.

We propose that the origin and evolution of the Minas de Henarejos basin can be explained by local control by a restraining bend of a sinistral strike-slip fault system along its eastern margin, related to the Teruel Fault System (Fig. 1B, 6C). This orientation is compatible with the observed NW-SE normal fault systems observed in other coeval basins, as the kinematic models of Christie-Blick and Biddle (1985) have shown.

This is consistent with an early extensional phase during the Early Permian in the Iberian Microplate as a diffuse, punctiform response, of the variscan basement to the stress caused along its northern and southern margins by major E-W dextral transform systems (Fig 6A), when the Variscan compressive stress field ceased (Arche and López-Gómez, 1996). It was expressed in coeval NW-SE normal extensional faults and N-S sinistral strike-slip faults and also coeval with the late phase of lithospheric collapse of the roots of the Variscan Orogen. This tectonic phase was short-lived (no more than 3 M.a.) in Central Iberia, but was the precursor of the widespread Alpine extensional regime developed during the Late Permian and most of the Mesozoic in the Iberian microplate.



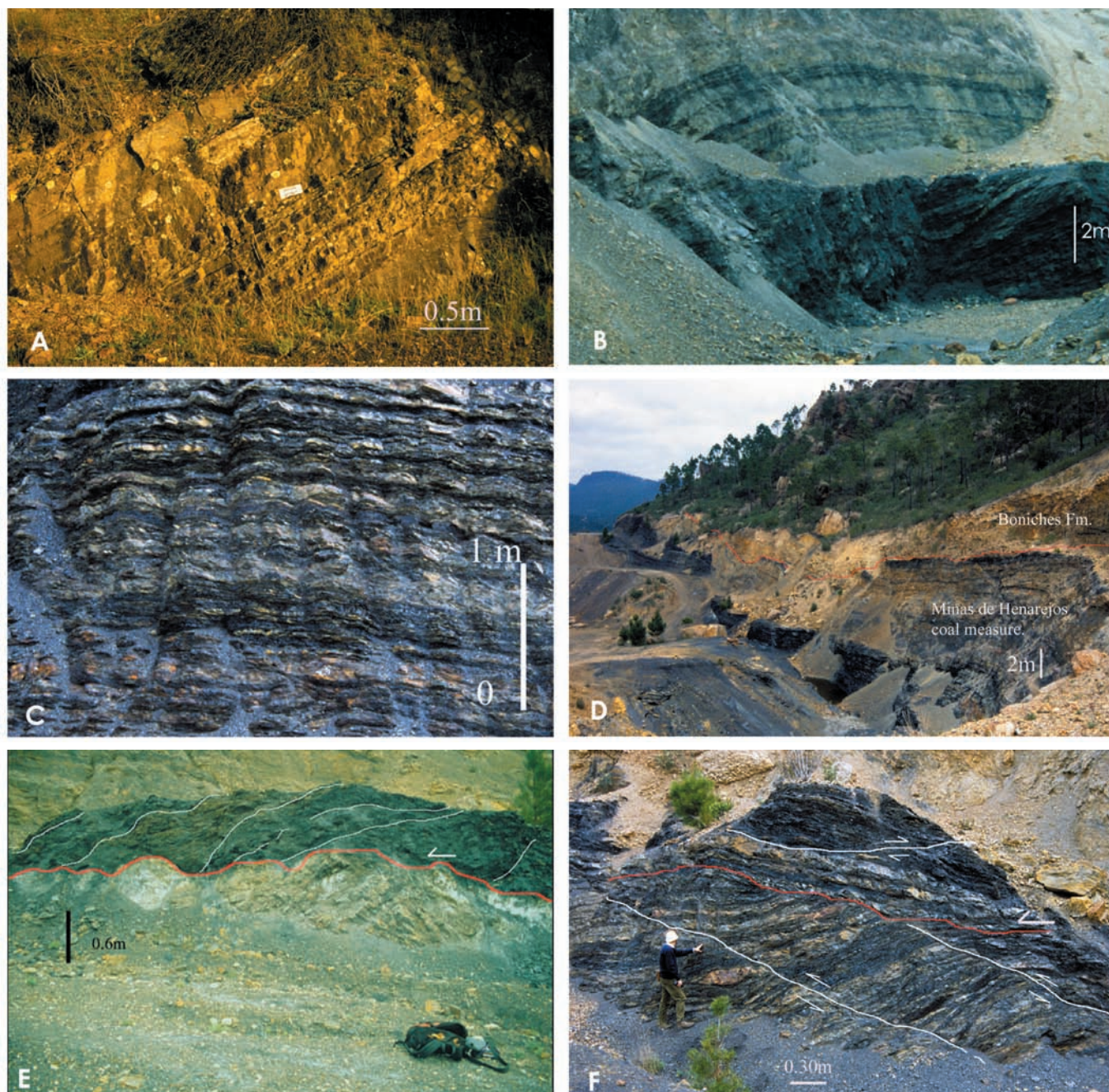


Fig. 5.- The Minas de Henarejos outcrop. A- Beds from the lower part of the section. B and C- Beds from the upper part of the section where coal beds and macroflora are located. D- The upper part of the section and the unconformity with the upper Boniches Conglomerates Formation. E and F- Syn-sedimentary compressive structures.

Fig. 5. El afloramiento de Minas de Henarejos. A- Niveles de la parte inferior de la columna estratigráfica. B y C- Niveles de la parte superior de la columna estratigráfica donde se localizan los niveles de carbón y la macroflora estudiada. D- Parte superior de la columna estratigráfica y su contacto discordante con la Formación Conglomerados de Boniches. E y F- Estructuras compresivas sinsedimentarias.

Of course, there are alternative hypothesis to the pure tectonic origin of these shortening structures, because they can be found in pure extensional regime, when detachments coeval with extension at the margins of the basins can cause local compressive structures along its surface in the sedimentary infilling, as illustrated by Djarar *et al.* (1996) in the Cevennes basin, France.

Another alternative is the formation of compressive structures associated to gravity gliding in the delta slope of many modern deltas, with frontal thrusting and folding of partially lithified beds (Coleman, 1988; Coleman *et al.*, 1983), but this type of deformation is usually concentrated in discrete horizons alternating with intervals with normal bedding, not the case of Minas de Henarejos basin.



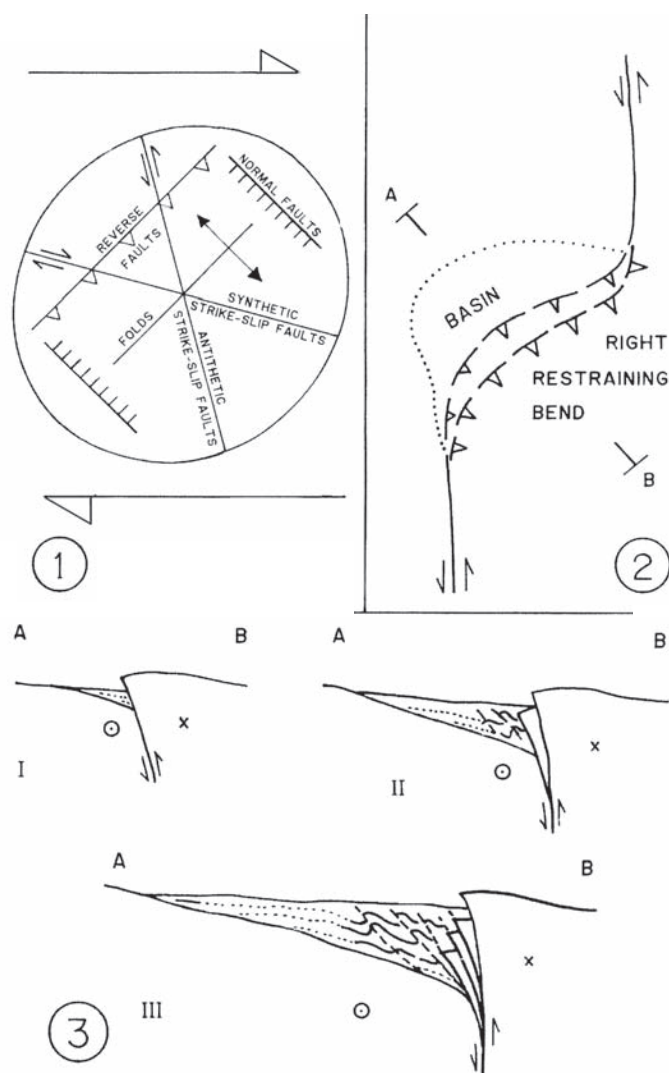


Fig. 6.- 1- Strain-induced structures in right-lateral strike-slip regime. 2- Postulated right restraining bend in the area and associated sedimentary basin during the activity of the sinistral strike-slip Teruel Fault as a possible origin of the Minas de Henarejos basin. 3- Progressive stages of infilling and deformation of the Minas de Henarejos Basin.

Fig. 6.- 1-Estructuras inducidas por los esfuerzos derivados de un régimen de fallas en dirección diestras. 2- Arco contractivo diestro postulado en la zona y cuenca sedimentaria asociada durante el periodo activo de la falla en dirección siniestra de Teruel como posible origen de la cuenca de Minas de Henarejos. 3- Estadios progresivos de relleno y deformación de la cuenca de Henarejos.

Only more detailed microtectonic field studies can elucidate the true origin of these shortening structures, but, in any case, they have a pre-Late Permian age, because the unconformable overlying Late Permian conglomerates are not affected by this kind of deformation, i. e.: they postdate the shortening event.

## 6. Conclusions

A- The Minas de Henarejos basin is probably coeval with the rest of Autunian basins of the Iberian Ranges.

The ambiguity of the macrofloral biostratigraphic data is larger than previously supposed and its temporal extension goes from the Late Carboniferous (Gzelian) to the Early Permian (Kazanian) at least.

B- The compressive syn-sedimentary structures in the Minas de Henarejos basin are unique in the Iberian Ranges Early Permian basin and are very likely related to a restraining bend in the sinistral Teruel N-S strike-slip fault system. A synformal basin was created in the underthrust block. The alternative hypothesis of syn-extensional detachments and local compression along its surface or gravity gliding in delta slopes with associated local thrusting cannot be ruled out.

C- The possibility of a local, late variscan compressional phase in this area is rejected.

D- The temporal range of terrestrial macrofloras must be carefully re-evaluated for the Late Carboniferous-Early Permian interval.

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